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INFLATION OF THE STOMACH WITH HYDROGEN GAS  
IN THE DIAGNOSIS OF WOUNDS AND PERFORATIONS OF THIS ORGAN.

*WITH THE REPORT OF A CASE.*

✓ BY

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PRINCIPLES OF SURGERY AND SURGICAL PATHOLOGY IN RUSH  
MEDICAL COLLEGE, CHICAGO, ILL.



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IN my paper on "Rectal Insufflation of Hydrogen Gas as an Infallible Test in the Diagnosis of Visceral Injury of the Gastro-intestinal Canal in Penetrating Wounds of the Abdomen," read in the Surgical Section of the American Medical Association, I incidentally called the attention of the medical profession to the value of inflation of the stomach as a diagnostic measure in cases of injury or perforation of this organ, in that part of the paper which referred to inflammation of the alimentary canal through the stomach tube. We should naturally expect that the alimentary canal could be inflated with more ease and with a less degree of force by following the normal peristaltic wave. That this is not the case will be seen from the following experiments:

EXPERIMENT VII.—Dog, weight 40 pounds (18 kilograms). After complete anæsthesia was effected,

*presented by author*



a flexible rubber tube was introduced into the stomach and the free end connected by means of a rubber tube with a four-gallon rubber balloon, containing hydrogen gas. Between the gas reservoir and the stomach-tube a manometer was interposed, registering accurately the force used in making the inflation. The inflation was made by compressing the rubber bag. A tube was introduced into the rectum to facilitate the escape of gas that might reach this portion of the intestinal tract. Under a pressure of one pound and a half the stomach dilated rapidly, and later the entire abdomen became distended and resonant on percussion, but no gas escaped per rectum. When the pressure was increased to two pounds (one kilogram) no further distention of the abdomen took place, as the gas escaped along the sides of the stomach tube. At this time respiration became greatly embarrassed, but was relieved on allowing gas to escape through the stomach tube. On compressing the abdomen firmly the distention disappeared almost completely; at the same time a large quantity of gas continued to escape through the stomach tube. Inflation was renewed, and under a pressure of one pound and a half the abdomen again became uniformly distended. When the pressure was increased to two pounds (one kilogram), the dog suddenly died and all efforts at resuscitation failed. On opening the abdomen the stomach was found enormously distended, reaching three inches below the umbilicus, and occupying almost the entire abdominal cavity. The upper half of the small intestine was distended; numerous points of sharp flexions were found among the different distended coils. The distended stomach had evidently encroached so much upon the abdominal space as to

render the greater part of the intestinal canal impermeable by pressure.

EXPERIMENT VIII.—Dog, weight 15 pounds. After the animal was placed fully under the influence of ether, the abdomen was opened and the cæcum and lower portion of the ileum drawn forward into the wound, and a large needle of an aspirator inserted into the ileum just above the ileo-cæcal valve. Through a rubber tube hydrogen gas was forced into the stomach. Under one pound (five hectograms) of pressure the stomach and upper portion of the intestines dilated readily. When the force was increased, the gas returned through the œsophagus along the sides of the stomach tube.

EXPERIMENT IX.—Dog, medium size. This animal was killed to ascertain the results of an experiment made for another purpose. Rubber balloon, containing hydrogen gas, and manometer were used for making the inflation. The tube through which the inflation was made was tied in the œsophagus. The abdomen was distended enormously, and on increasing the pressure to  $3\frac{3}{4}$  pounds ( $1\frac{1}{2}$  kilograms) still no gas escaped through the rectal tube. The abdomen was then opened, when the stomach was found so enormously distended that it filled almost the entire abdominal cavity. About one-fourth of the length of the small intestine was found distended, and among the distended loops numerous acute flexions could be seen. After the abdomen was opened, under long and continuous distention, the peritoneal covering of the stomach gave way, when the manometer registered only one pound and a half of pressure.

EXPERIMENT X.—Dog, weight 18 pounds (8 kilograms). Immediately after death the œsophagus was isolated and the tube of the hydrogen gas inflator securely tied in, and a glass tube was inserted

into the rectum. Under a pressure of  $2\frac{3}{4}$  pounds (1.2 kilograms), registered by the manometer, the gas first dilated the stomach and then passed along the intestine until it escaped in a steady stream through the rectal tube, when it was ignited. On opening the abdomen the stomach was found greatly distended, while the distention of the intestines was a great deal less marked. None of the tunics of the stomach or intestines was injured.

EXPERIMENT XI.—Dog, weight 20 pounds (9 kilograms). Animal etherized and a flexible tube connected with the gas inflator introduced into the stomach and a glass tube into the rectum. On inflation the stomach became gradually distended, and when the pressure had reached  $1\frac{1}{2}$  pounds (0.6 kilogram) the dog vomited and a good deal of gas escaped at the same time. Inflation was again commenced and was followed by uniform distention and tympanites over the entire abdomen; when the pressure reached  $2\frac{1}{2}$  pounds (1 kilogram) the gas escaped from the rectum, and when ignited burned with a steady, blue flame. The experiment was followed by no unfavorable symptoms.

EXPERIMENT XII.—Dog, weight 12 pounds ( $5\frac{1}{2}$  kilograms). Under the influence of ether, inflation with hydrogen gas, in the same manner as in the last experiment. As soon as the stomach became well distended and the manometer registered  $1\frac{1}{2}$  pounds of pressure, vomiting occurred, attended by a free escape of gas, which was followed by collapse of the distended epigastric region. When inflation was again resumed, it was noted that any increase of pressure over 1 pound (0.45 kilogram) was followed by regurgitation of gas, and, on this account, it was found impossible to inflate the lower portion of the

intestinal tract. No unfavorable symptoms followed the experiment.

EXPERIMENT XIII.—Dog, weight 28 pounds ( $12\frac{1}{2}$  kilograms). Under the influence of ether, inflation with hydrogen gas through a stomach tube. As soon as the pressure was increased to more than 1 pound (0.45 kilogram), the gas escaped along the sides of the tube through the œsophagus; consequently only the upper portion of the abdomen could be distended, and the inflation evidently did not extend much beyond the stomach. The experiment was repeated several times, with the same result. The animal remained perfectly well after the experiment.

EXPERIMENT XIV.—Dog, weight 12 pounds (5 kilograms). Inflation of stomach with hydrogen gas under full anæsthesia. The effect of the inflation was the same as in the last experiment, only the stomach and upper portion of the small intestine could be distended, and further inflation was impossible, as the gas escaped from the stomach as soon as the pressure exceeded 1 pound (0.45 kilogram). A large needle of an aspirator was passed through the linea alba into the stomach, and the gas which escaped through it, on being lighted, burned with the characteristic blue flame. After the needle was withdrawn, the inflation was continued, to ascertain if the puncture in the stomach would allow the escape of gas into the peritoneal cavity. The inflation was continued until the entire abdomen was distended by the gas. That the distention and tympanites were due to the presence of gas in the peritoneal cavity became evident, as they remained after the stomach had been emptied of its gas, and, on percussion, it was ascertained that the entire liver dullness had disappeared. The dog recovered without symptoms of peritonitis or any other ill effects from the experiment.

These experiments demonstrate conclusively that it is more difficult to inflate the alimentary canal from above downward than from below upward, as in the living animal I succeeded in only one instance in forcing hydrogen gas from the mouth to the anus, while in others a degree of force sufficient to rupture the peritoneal coat of the stomach only effected distention of the stomach and upper portion of the intestinal canal. It is evident that great distention of the stomach constitutes an important factor in causing or aggravating intestinal obstruction, as it effects compression, which again causes impermeability of the intestines, or aggravates conditions arising from an antecedent partial permeability, by producing sharp flexions among the distended coils of the intestines.

*For diagnostic and surgical purposes, the stomach can be readily inflated almost to any extent through a stomach tube, and when it becomes necessary to ascertain the presence of a visceral wound or perforation of this organ, this method of inflation may be resorted to with advantage.*

I have recently had an excellent opportunity to apply this test in a case of gunshot wound, of the chest and abdomen, in which, without it, it would have been impossible to make a correct diagnosis. The insufflation made the diagnosis positive, and the information obtained from it justified the treatment by laparotomy, although the general symptoms were so grave that it appeared doubtful if the patient would live long enough to complete the operation.

C. H., a man, seventy-two years of age, brought to the Milwaukee Hospital by the police patrol, at 7 A.M., July 9, 1888, for a suicidal, bulldog pistol (44-calibre) wound of the chest, inflicted about two hours previously. Pistol held in the left hand, as ascertained from the patient and confirmed subsequently by examination of the direction of the bullet. The patient stated that he had pointed the pistol toward the heart.

*Examination, 7 A.M.* Wound of entrance situated in the left sixth intercostal space, surrounded by emphysema. Seventh rib fractured at junction of cartilage and bone. No wound of exit. Patient conscious; complains of severe pain in the epigastric region, increased by pressure. Pulse rapid and weak. Vomits and expectorates blood. Area of liver dullness diminished. Percussion and respiratory sounds normal. No evidence of hemo- or pneumothorax.

9 A.M. Flexible tube introduced and stomach inflated with hydrogen gas from a four-gallon rubber balloon. Inflation effected by continuous pressure on the balloon. Gas escaped and ignited at the wound of entrance with an audible sound. Field of operation thoroughly disinfected. Patient etherized and laparotomy made by incision from the ensiform cartilage to the umbilicus. The omentum and stomach were drawn forward into the wound. A large perforation, about one and a half inches in length (due to the oblique direction of the bullet), was found in the stomach, midway between the pylorus and the cardiac end on the greater curvature. Stomach partially filled with coagulated blood. With the index finger introduced through this perforation, another was detected on the lesser curvature and near the cardiac end. The omentum, which was adherent to the colon, was torn through and

exploration of the posterior surface of the stomach failed to reveal the old site of the second wound which was felt by the digital exploration of the interior of the organ. The blood-clots were removed from the stomach by irrigation through the lower wound.

For the purpose of locating with accuracy the second wound, the stomach was inflated through the bullet wound on the anterior surface with hydrogen gas, the escape of which made it easy to locate the second wound. The omental opening was enlarged by tearing and the perforation was discovered on the posterior surface at the lesser curvature and close to the cardiac orifice. Great difficulty was experienced in dragging the stomach sufficiently forward and downward into the abdominal incision to enable me to suture the perforation, which was two inches in length. It was closed by a continuous Lembert suture of silk, the anterior wound by a Czerny-Lembert suture.

Considerable blood was found behind the stomach, in the region of the pancreas. The hemorrhage had evidently taken place from lacerated vessels of considerable size at both perforations as well as from vessels in the pro-peritoneal space. Probable direction of the bullet from above downward, backward and to the right. At this stage collapse from shock and hemorrhage supervened. The body was partially inverted and a saline infusion of fifteen ounces of a six-tenths per cent. salt solution performed. Brandy was injected subcutaneously and faradic current applied to phrenic and pneumogastric nerves without any apparent effect. Death occurred before the abdominal wound could be closed.

The abdominal incision was sutured and inflation of hydrogen gas, per rectum, made to test the con-

dition of the sutured stomach. A stomach tube was introduced and the gas, under a pressure of not more than a pound, forced through the entire gastro-intestinal canal, igniting and burning with a continuous flame as it escaped from the end of the stomach-tube, which showed that no gas escaped through the sutured wounds. Post-mortem was made immediately. Wound of entrance in the sixth intercostal space, seventh rib fractured at junction of cartilage and bone, both pleural cavities obliterated by adhesions, margin of lower lobe of left lung perforated, pericardium intact, lacerated opening in diaphragm admitting two fingers. Perforations in stomach as described. Liver and spleen not injured, upper margin of tail of pancreas lacerated. Bullet passed to left of the aorta, entered the left crus of the diaphragm, fractured the last rib at the neck and perforated the spinal column, entering between the last dorsal and first lumbar vertebra, escaping through the body of the latter and fracturing its right transverse process. Bullet found in the subcutaneous connective tissue of right lumbar region. The spinal canal was opened by the bullet in its passage through the vertebra, and loose fragments of bone lay in the canal. The membranes of the cord were intact and the cord itself uninjured.

The location of the wound of entrance in this case did not indicate that the bullet had entered the abdominal cavity unless the revolver was held in the left hand ; in that case, as it was directed toward the heart, the track of the bullet would be necessarily downward, backward and from left to right. Taking it for granted that the bullet took this direction it would still have been possible for the stomach to

escape injury. The circumscribed emphysema around the external wound and the hemoptysis, as well as the location of the wound, left no doubt that the lower lobe of the lung was injured. The absence of hemothorax and pneumothorax was explained by the post-mortem, as the left pleural cavity was found completely obliterated by adhesions. Under a pressure of not more than half a pound to the square inch, the hydrogen gas was forced through the external wound where it was lighted and burned in a large continuous flame until it was extinguished by compression with a large moist sponge. Very little gas was found in the peritoneal cavity.

In perforation of the stomach without an external wound, inflation of the organ with hydrogen gas will render the abdomen universally tympanitic, as the gas will escape into the peritoneal cavity and, as it always occupies the highest plane, on account of its low specific gravity, it will push the abdominal organs backward, and thus it happens that the liver dullness disappears completely, which fact alone, if established, makes the diagnosis of perforation positive, unless the organ is fixed in its place by peritoneal adhesions, the result of a previous peri-hepatitis.

In cases of perforating ulcer of the stomach or duodenum, if this simple diagnostic measure is resorted to in time, it will prove the means, by prompt surgical treatment, of saving many a life that has hitherto been sacrificed under the expectant plan of treatment.

It has been claimed that hydrogen gas is objectionable for purposes of inflation, as when it is

## DIAGNOSIS OF WOUNDS OF STOMACH. II

mixed with a certain proportion of oxygen or atmospheric air it forms an explosive compound. Against this argument I can say that no accidents of any kind have occurred during any of my numerous experiments on animals, nor in the few cases in which it has been applied in practice. Hydrogen gas has the lowest specific gravity of all the gases known, and on this account, as well as from its non-toxic qualities, it should always be preferred to other gases and atmospheric air, simple or medicated. The hydrogen gas test appeals both to the sense of sight and hearing, if successful in cases of perforating wounds. The preparation of the gas is so simple and rapid that its use is applicable not only in hospital and city but also in country practice.

I have recently been able to make a correct diagnosis in several cases of obscure abdominal tumors, by resorting to stomach and rectal inflation of hydrogen gas, which, without these diagnostic measures, would have been impossible, short of an exploratory laparotomy. The relation of tumors of the abdominal cavity to the different organs and the peritoneal cavity can be mapped out and studied with great accuracy by dilating the stomach and different portions of the intestinal canal, at intervals, by inflation with this harmless and readily procurable gas.





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